
بسم الله الرحمن الرحيم

Case Discussion In Mechanical Ventilation

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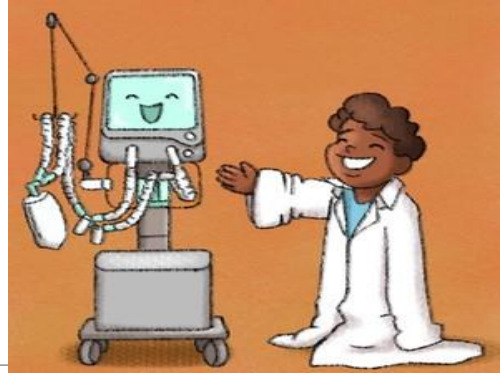
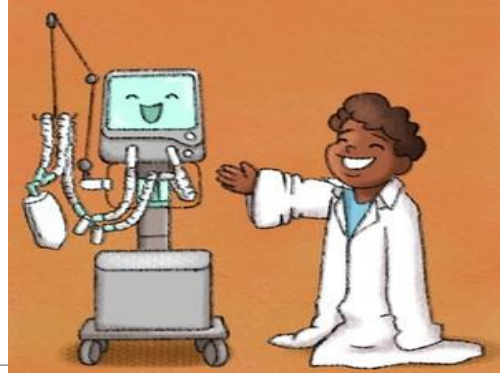
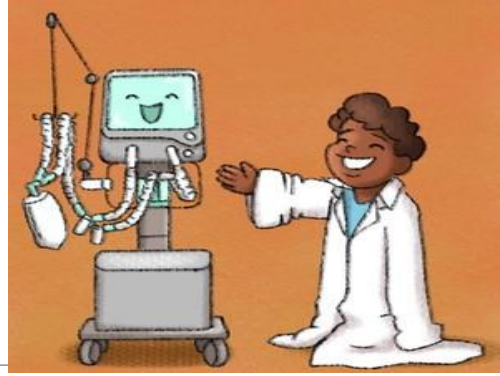


- The most common reason for instituting MV is to treat respiratory distress in patients who are unable to achieve effective gas exchange
- This goal can be accomplished by setting an appropriate tidal volume (V_T) and respiratory rate (f) to achieve a desired minute ventilation ($\dot{V}_E$)

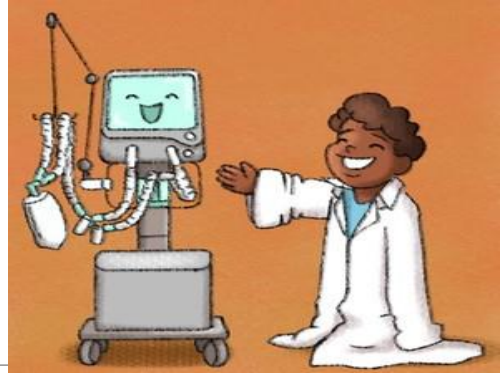
Initial Ventilator Settings



- ✓ Including :
- $\dot{V}_E$ settings (V_T and f)
- Inspiratory gas flow and FIO_2
- Flow waveform
- (I:E) ratio
- Pressure limit
- Inflation hold (inspiratory pause)
- Inspiratory pressure
- Positive end-expiratory pressure (PEEP)



- The primary goal of VC-CMV is to achieve a $\dot{V}_E$ that matches the patient's metabolic needs.
- A typical healthy person at rest has a total oxygen consumption of about 250 mL/min, and a CO2 production of about 200 mL/min
- As the patient's metabolic rate increases, ventilation must change to meet the need for increased oxygen uptake and CO2 removal



Minute Ventilation ($\dot{V}_E$)

Men $\dot{V}_E = 4 \times$ body surface area (BSA)

Women $\dot{V}_E = 3.5 \times$ BSA

Tidal Volume (V_T)

Minimum of 6 mL/kg ideal body weight (IBW)

Respiratory Frequency (f)

$f = \dot{V}_E / V_T$

Ideal body weight (men) = 50 kg + 2.3 kg x (height, in - 60)
Ideal body weight (women) = 45.5 kg + 2.3 kg x (height, in - 60)

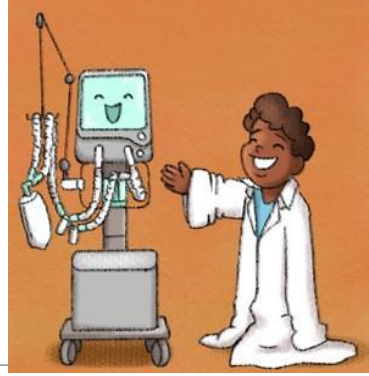
Women: IBW (lbs) = 105 + 5(H – 60),
where *H* is height in inches.

For example, the IBW of a 66-inch-tall woman is 105 + 5(66 – 60) = 105 + 5(6) = 135 lb (61.4 kg). (To convert to kilograms, divide by 2.2.)

Men IBW (lbs) = 106 + 6(H – 60).

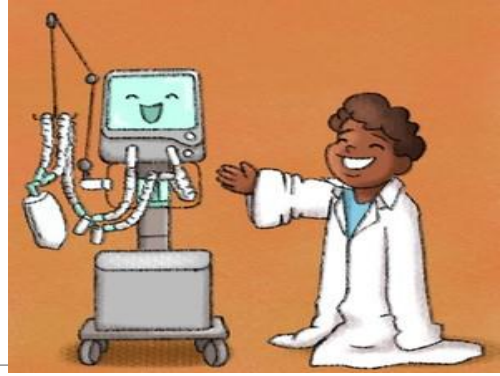
For example, the IBW of a 66-inch-tall man is 106 + 6(66 – 60) = 106 + 6(6) = 142 lb (64.5 kg).

Initial ventilator settings for specific patient situations



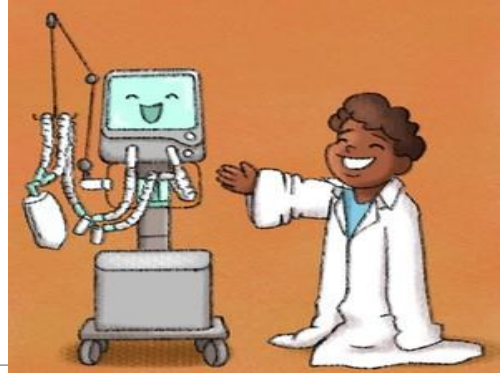
Chronic Obstructive Pulmonary Disease

- Patients with COPD have increased Raw and CL, which, when combined, cause significant expiratory obstruction, lengthen the time constant, and lead to air trapping
- COPD require MV …with another problem, such as a respiratory infection…acute on chronic respiratory failure.

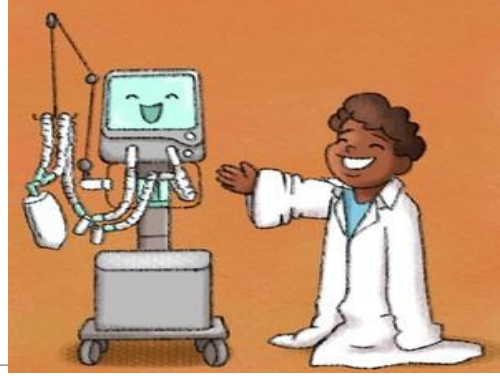


- MV in COPD ….increased morbidity …air trapping, nosocomial infections, barotrauma and volutrauma, cardiac problems, aspiration, and difficulty weaning.
- The goals of MV are to maximize patient-ventilator synchrony, reduce WOB and patient anxiety, and avoid the complications associated with MV , such as VAP and ventilator induced lung injury(VILI)

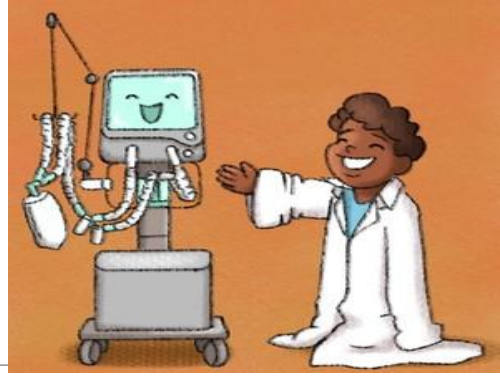
Guidelines for patients with COPD



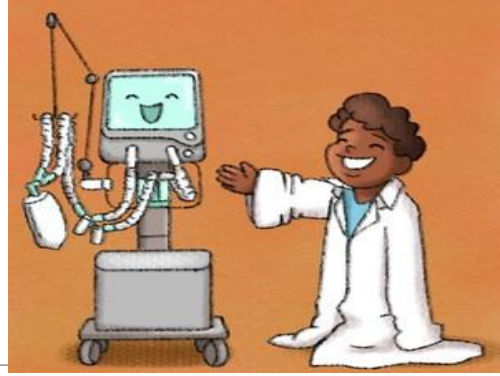
- If possible, use NIV to avoid problems associated with artificial airways.
- Bilevel positive airway pressure (bilevel PAP) is ideal for patients with chronic pulmonary disorders
- A ventilator mode that you feel most familiar



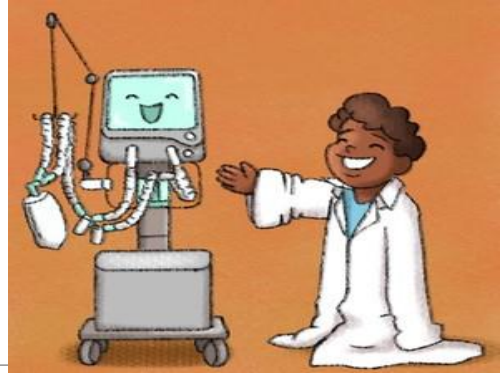
- VC- or PC-CMV may unload the work of the respiratory muscles more than IMV
- Using patient-triggered CMV in an alert patient with COPD may increase the risk of hyperinflation and elevated lung pressures
- This mode should be monitored carefully.



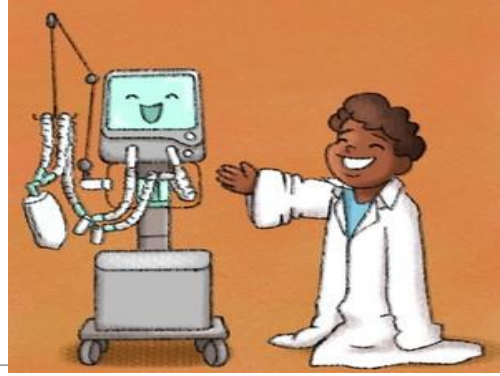
- Adjust the peak inspiratory flow to meet the patient's demand in VC-CMV using the descending flow pattern: flow >60 L/min.
- In patients with COPD and asthma, where airway obstruction and resistance are high, an initial V_T of 6 to 8 mL/kg with a rate of 8 to 16 breaths/min, and T_I 0.6 to 1.2 sec is acceptable.



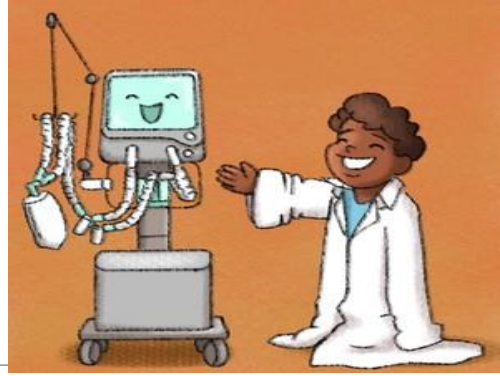
- PEEP 5 cm H2O or lower, or about 50% of auto-PEEP, should be used initially.
- Monitor for and minimize dynamic hyperinflation (auto-PEEP) by setting the lowest possible $\dot{V}_E$ that produces acceptable gas exchange targeting the patient's baseline PaCO2 and PH.
- Provide the longest (T_E) possible. This may include decreasing T_I, increasing T_E, reducing f or V_T, and accepting hypercapnia
- Patients with COPD are usually ventilated in their normal PaCO2 range (e.g., PaCO2 = 50 to 60 mm Hg; pH 7.3 to 7.4.)



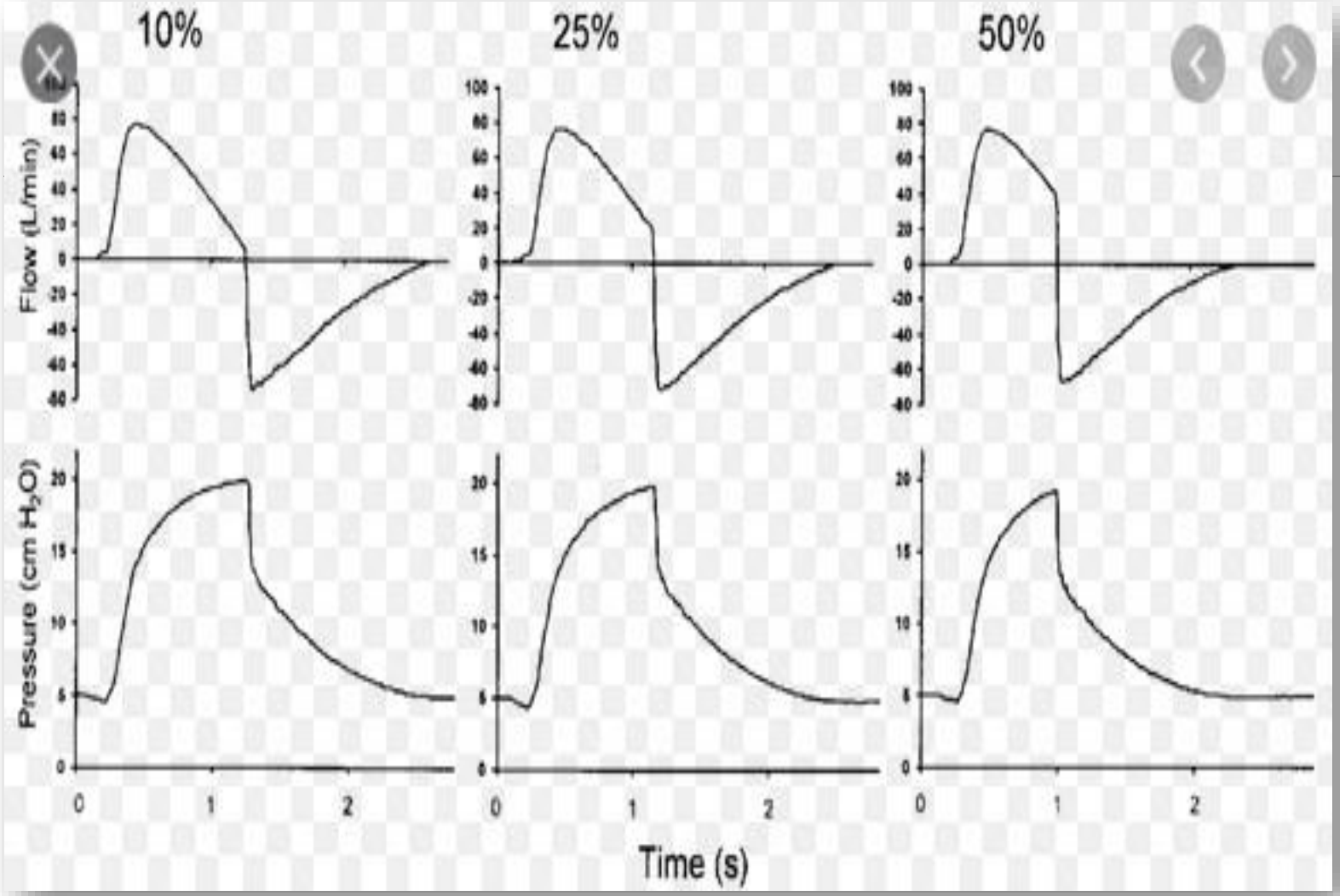
- Set PEEP near 80% of the auto-PEEP level, but do not exceed it (3 to 5 cm H2O is often adequate). If PIP begins to rise because PEEP is increased, the safe PEEP level has probably been exceeded and will result in lung overinflation.
- P_{plat} should be maintained < 30 cm H2O to avoid alveolar overdistention and lung injury.
- Accurate measurement of P_{plat} may require sedation and paralysis

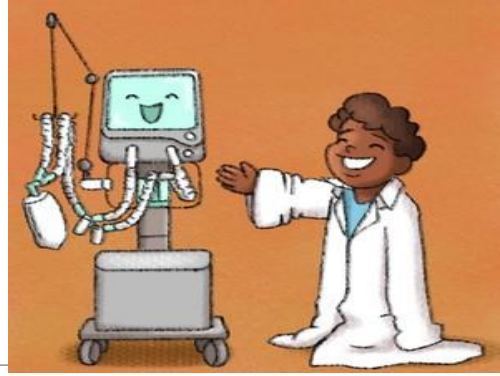


- Maintain PaO2 at 55 to 75 mm Hg or near the patient's normal PaO2, with FIO2 less than 0.5, unless the patient's condition worsens and requires more oxygen.
- Pressure control ventilation (PC-CMV) may be ideal for this group of patients for several reasons
- PC-CMV provides flow on demand to meet the patient's needs

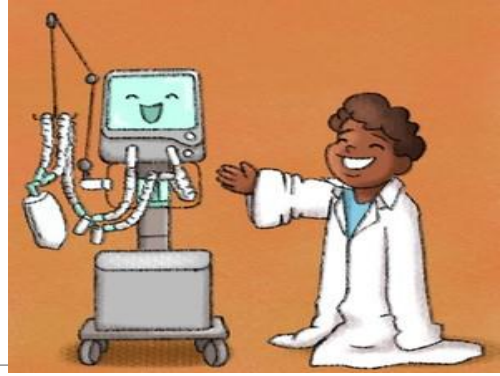


- PC-CMV has a distinct advantage over PSV for this patient population because inspiration during PSV can be too long or too short, depending on the patient's active breathing patterns.
- This can result in increased WOB and poor patient-ventilator synchrony. Auto-PEEP can be a lethal complication. Current ventilators that allow an adjustable expiratory flow cycle may allow for the use of PSV in COPD


10%
25%
50%
Flow (L/min)
Pressure (cm H_2O)
Time (s)

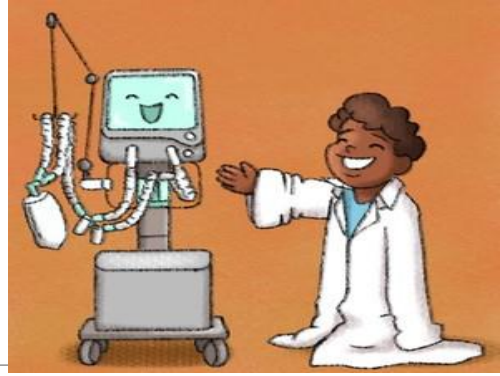


- Volume-assured pressure support (VAPS) or volume support (Servo-i) can also provide pressure ventilation with a set targeted volume delivery .
- Although these modes are also well suited for patients with COPD, clinicians must be familiar with their use.

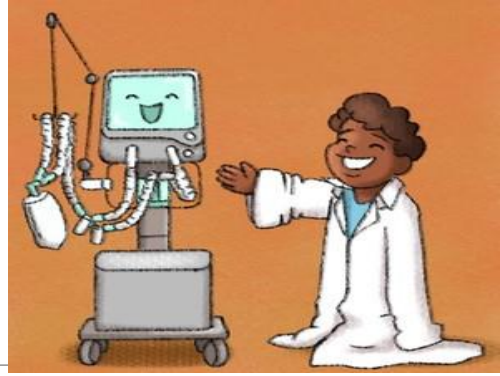


- An important part of patient care is providing adequate hydration and pharmacologic therapy (i.e., bronchodilators and corticosteroids) to reverse airflow limitation.
- Secretions must be mobilized and removed, and if infections are present, appropriate antibiotic medication must be administered.
- The primary problem necessitating ventilation must be corrected to ensure that weaning will be successful.
- Because many of these patients are malnourished, an evaluation of their nutritional needs must be part of any follow-up program

Asthma



- Exacerbation of acute severe asthma that requires mechanical ventilation are among the most difficult to manage.
- Increased Raw from bronchospasm, increased secretions and mucosal edema increase the incidence of air trapping.
- Trapped air can cause uneven hyperexpansion of various lung units, which can rupture or compress other areas of the lungs, leading to pneumothorax, pneumomediastinum, subcutaneous emphysema and barotrauma.

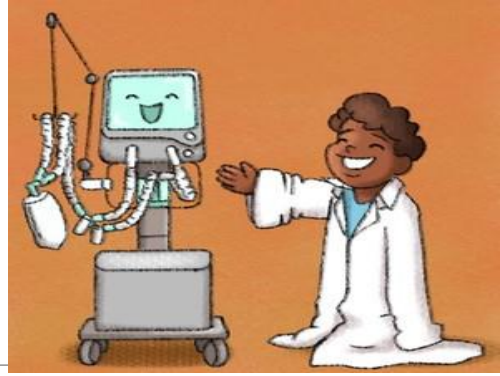


- Progressive hypoxemia further enhances the patient's drive to breathe and compounds anxiety.
- Even aggressive treatment with bronchodilators and steroids might not be enough to reverse the course of an acute asthma exacerbation.

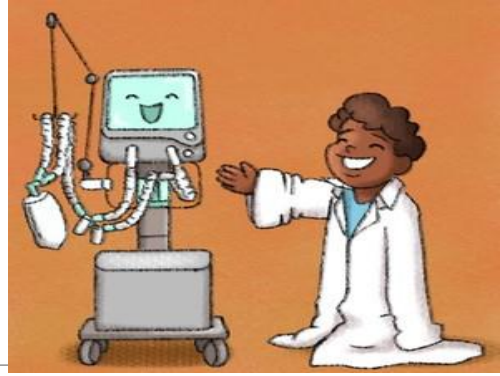
Indications for MV in Acute Exacerbation of Asthma

1. Exhaustion (e.g., respiratory rate progressively decreases and level of consciousness is altered), with developing metabolic acidosis, and decreasing pH in the presence of a normal or rising carbon dioxide pressure (P_aCO_2).
2. If audible, bilateral wheezes become distant as air trapping increases (e.g., breath sounds absent, chest hyperresonant to percussion or fixed on palpation).
3. Severe hypoxemia while receiving oxygen (e.g., inability to oxygenate with supplemental oxygen).
4. Chest radiograph with depression of the hemidiaphragms and increased radiolucency, suggestive of air trapping.
5. Altered mental status, confusion, or decreased level of consciousness.
6. Life-threatening dysrhythmias.
7. P_aCO_2 rises while pH declines (e.g., ≥40 mm Hg; pH ≤7.25 [progressive respiratory acidosis superimposed on a metabolic acidosis]).
8. Cardiac or respiratory arrest.

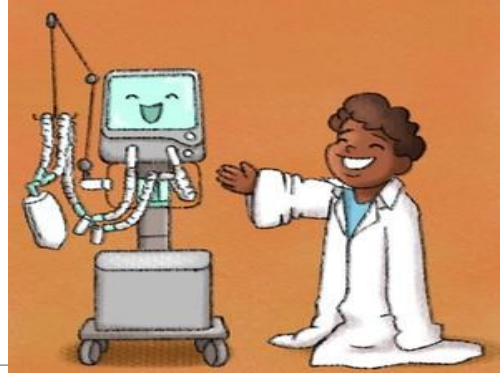
Guidelines for patients with asthma



- VC- or PC-CMV are acceptable modes immediately following intubation
- It is easier to control airway pressure with PC-CMV.
- Maintain peak and plateau pressures at minimal levels. PIP may be high due to the high Raw and the use of high inspiratory gas flows.
- Alveolar (plateau) pressures must still be maintained at <30 cm H2O

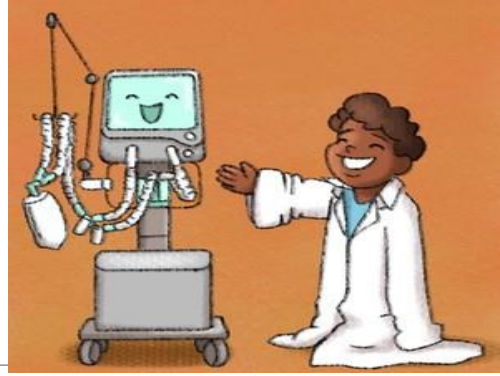


- Ensure that the patient's oxygenation status is adequate by using an FIO2 as needed to achieve a PaO2 from 60 to 100 mm Hg (usually FIO2 ≥0.5). Monitor hemodynamic status to ensure cardiac output is stable.
- Permissive hypercapnia (PaCO2 45 to 80 mm Hg) is acceptable as long as pH is acceptable (i.e., ≥7.2)
- Tris-hydroxymethyl-aminomethane [THAM] or bicarbonate is administered by some physicians to keep pH >7.2



- If the ventilator settings cannot accommodate the patient's needs, the use of sedatives and paralytics may be necessary

- When patients are spontaneously breathing and having trouble triggering breaths, setting the $PEEP_E$ at about 80% of $PEEP_I$ may allow for easier triggering of ventilator breaths.

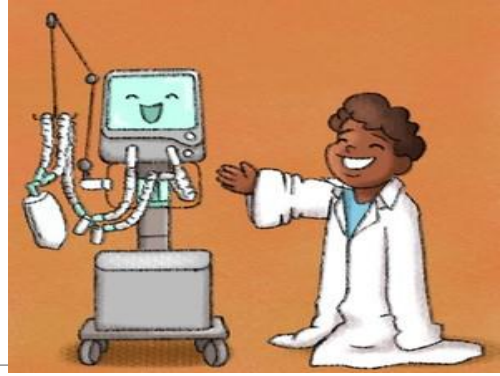


Reduce the incidence of air trapping by providing long expiratory times:

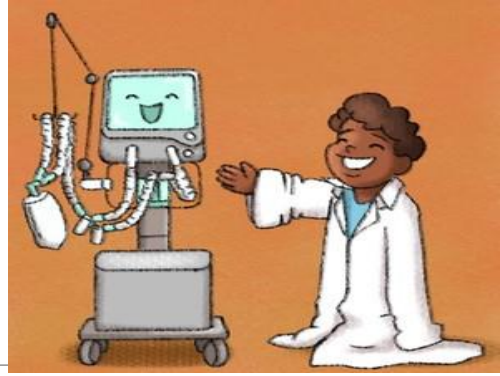
- f = < 8 breaths/min
- V_T =6-8mL/kg
- Ti =<1sec
- inspiratory gas flow = 80 to 100 L/min
- descending flow waveform

Neuromuscular disorders

- Myasthenia gravis, amyotrophic lateral sclerosis, muscular dystrophy, postpolio syndrome, guillain-barré syndrome, tetanus, cervical spinal cord injury, and botulism
- Have a normal ventilatory drive and normal or near-normal lung function.
- Respiratory muscle weakness, limit these patients' abilities to cough and clear secretions
- Atelectasis and pneumonia

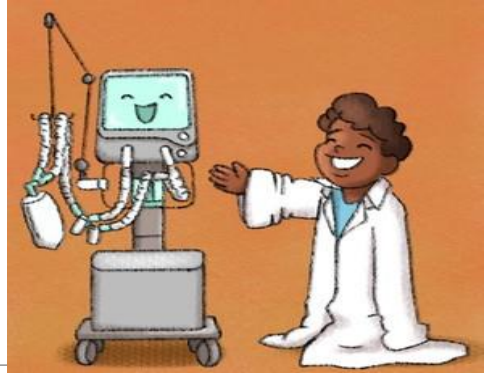


- PPV is most often selected and can be either noninvasive or invasive.
- Because these patients often have normal lung function, they are at low risk for barotrauma and are most comfortable when ventilated with higher V_T values (i.e., 6 to 8 mL/kg) and high inspiratory flow rates greater than 60 L/ min using a constant flow or descending flow pattern when VC-CMV is used.

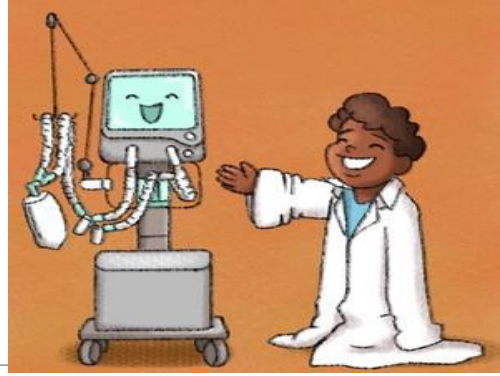


- Some clinicians prefer starting with a lower V_T and adjusting the volume as needed

Guidelines for patients with neuromuscular disorders

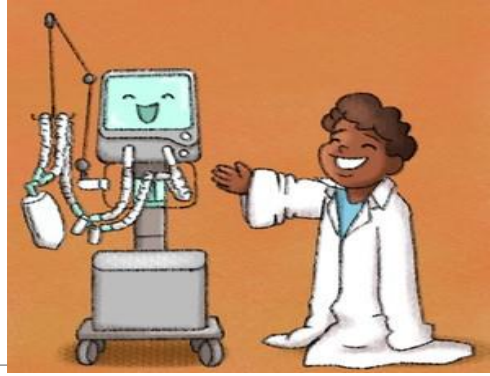


- Full or partial support
- Negative or positive pressure ventilation
- Noninvasive or invasive ventilation
- Assist/control mode (CMV)
- Volume control ventilation
- VT (6 to 8 mL/kg) while maintaining the P_{Plat} at less than 30



- f = 8 to 16 breaths/min
- Inspiratory flow rates ≥60 L/min to meet patient need (T_I about 1 second to start)
- Flow waveform: constant or descending flow pattern
- PEEP = 5 cm H2O may be needed to relieve dyspnea
- FIO2 = 0.21

Closed head injury



- CPP = MAP– ICP
- Normal values for MAP are 90 to 95 mm Hg and ICP less than 10 mm Hg
- Normal CPP is 80 to 85 mm Hg
- Values of CPP lower than 60 mm Hg indicate poor cerebral perfusion

Indications for MV in patients with head injuries

Assisted Ventilation

1. Respiratory depression associated with injury. It may be manifested as Cheyne-Stokes respiration, central neurogenic hyperventilation, or apnea.
2. Additional injuries to the chest, abdomen, back, or neck.
3. Use of medications that depress respiration.
4. Neurogenic pulmonary edema (an acute respiratory distress syndrome [ARDS]-like pattern that can occur following head trauma).
5. Impending or actual cardiac arrest.
6. Upper airway compromise (e.g., presence of stridor or loss of airway clearance mechanisms).
7. Aspiration at the time of loss of consciousness.

Airway Management (Intubation)

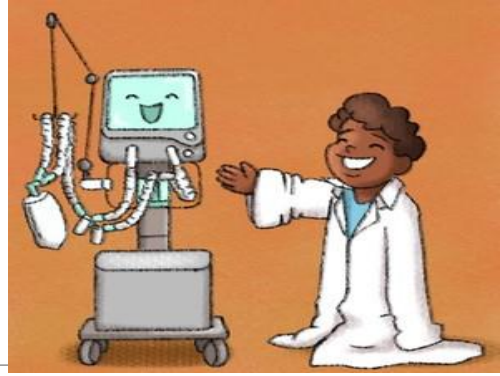
1. Head injury (particularly with Glasgow Coma Score* of ≤8).
2. Face, jaw, neck injuries with bleeding.

Oxygen Delivery

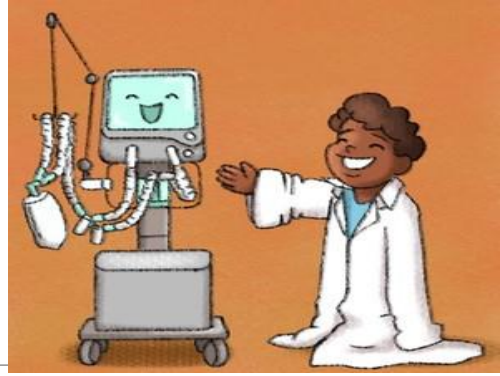
1. Head injury.
2. Pulmonary contusion, edema, or both.

Guidelines for patients with a closed head injury

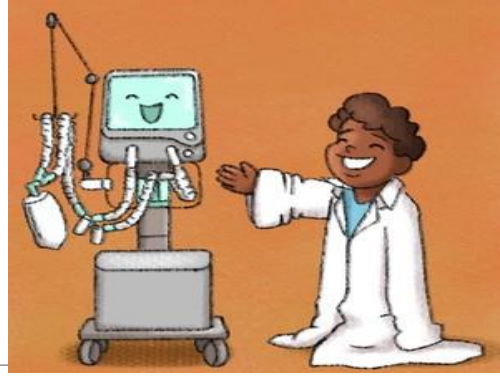
- There is a high risk for vomiting and aspiration
- Orotracheal intubation is often required.
- PC-CMV and PEEP can actually increase ICP.
- These patients often have normal lungs, so high P_{alv} can be transmitted to the blood vessels, thus affecting venous return from the head.



- When there is acute uncontrolled increased ICP, maintain PaCO2 from 25 to 30 mm Hg or titrate the ICP if it is being monitored.
- Provide full ventilatory support to start.
- Either PC- or VC-CMV can be used.
- Maintain V_T from 6 to 8 mL/kg IBW while maintaining P_{plat} at less than 30 cm H2O.
- An f of 15 to 20 breaths/min to provide normal acid–base status, as long as auto-PEEP is avoided

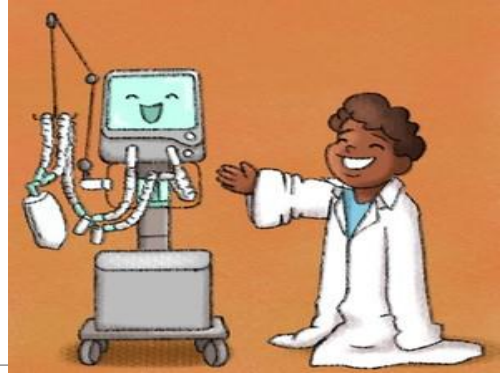


- FIO2 = 1.0 initially and titrate as needed to keep PaO2 from 70 to 100 mm Hg to avoid hypoxemia.
- High inspiratory flow (>60 L/min) to keep T_I short, about 1 second (avoid auto-PEEP) using a descending ramp pattern or constant flow pattern.
- PEEP = 0 to 5 cm H2O, as long as ICP is being measured and is 10 mm Hg or less
- Because PEEP can increase ICP, it is used only if necessary to avoid severe hypoxemia.



- Suctioning and chest physiotherapy can dramatically increase ICP but maintaining a clear airway is also essential
- Monitor for complications of pulmonary infections and pulmonary emboli.

Acute Respiratory Distress Syndrome



PART I: VENTILATOR SETUP AND ADJUSTMENT

1. Calculate predicted body weight (PBW)
   Males = 50 + 2.3 [height (inches) - 60]
   Females = 45.5 + 2.3 [height (inches) -60]
2. Select any ventilator mode
3. Set ventilator settings to achieve initial V_T = 8 ml/kg PBW
4. Reduce V_T by 1 ml/kg at intervals ≤ 2 hours until V_T = 6ml/kg PBW.
5. Set initial rate to approximate baseline minute ventilation (not > 35 bpm).
6. Adjust V_T and RR to achieve pH and plateau pressure goals below.

OXYGENATION GOAL: PaO_2 55-80 mmHg or SpO_2 88-95%

Use a minimum PEEP of 5 cm H_2O. Consider use of incremental FiO_2/PEEP combinations such as shown below (not required) to achieve goal.

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

Higher PEEP/lower FiO2

FiO_2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5
PEEP	5	8	10	12	14	14	16	16

FiO_2	0.5	0.5-0.8	0.8	0.9	1.0	1.0
PEEP	18	20	22	22	22	24

PLATEAU PRESSURE GOAL: ≤ 30 cm H_2O

Check Pplat (0.5 second inspiratory pause), at least q 4h and after each change in PEEP or V_T.

If Pplat > 30 cm H_2O: decrease V_T by 1ml/kg steps (minimum = 4 ml/kg).

If Pplat < 25 cm H_2O and V_T< 6 ml/kg, increase V_T by 1 ml/kg until Pplat > 25 cm H_2O or V_T = 6 ml/kg.

If Pplat < 30 and breath stacking or dys-synchrony occurs: may increase V_T in 1ml/kg increments to 7 or 8 ml/kg if Pplat remains ≤ 30 cm H_2O.

pH GOAL: 7.30-7.45

Acidosis Management: (pH < 7.30)

If pH 7.15-7.30: Increase RR until pH > 7.30 or $PaCO_2$ < 25 (Maximum set RR = 35).

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If pH < 7.15: Increase RR to 35.

If pH remains < 7.15, V_T may be increased in 1 ml/kg steps until pH > 7.15 (Pplat target of 30 may be exceeded).

May give $NaHCO_3$

Alkalosis Management: (pH > 7.45) Decrease vent rate if possible.

I: E RATIO GOAL: Recommend that duration of inspiration be $\leq$ duration of expiration.

PART II: WEANING

A. Conduct a SPONTANEOUS BREATHING TRIAL daily when:

1. $FiO_2 \leq 0.40$ and PEEP ≤ 8 OR $FiO_2 \leq 0.50$ and PEEP ≤ 5.
2. PEEP and $FiO_2 \leq$ values of previous day.
3. Patient has acceptable spontaneous breathing efforts. (May decrease vent rate by 50% for 5 minutes to detect effort.)
4. Systolic BP ≥ 90 mmHg without vasopressor support.
5. No neuromuscular blocking agents or blockade.

B. SPONTANEOUS BREATHING TRIAL (SBT):

If all above criteria are met and subject has been in the study for at least 12 hours, initiate a trial of UP TO 120 minutes of spontaneous breathing with FiO2 $\leq$ 0.5 and PEEP $\leq$ 5:

1. Place on T-piece, trach collar, or CPAP $\leq$ 5 cm H_2O with PS $\leq$ 5
2. Assess for tolerance as below for up to two hours.
   - a. $SpO_2 \geq 90$: and/or $PaO_2 \geq 60$ mmHg
   - b. Spontaneous $V_T \geq 4$ ml/kg PBW
   - c. RR $\leq$ 35/min
   - d. pH $\geq$ 7.3
   - e. No respiratory distress (distress= 2 or more)
     - HR > 120% of baseline
     - Marked accessory muscle use
     - Abdominal paradox
     - Diaphoresis
     - Marked dyspnea
3. If tolerated for at least 30 minutes, consider extubation.
4. If not tolerated resume pre-weaning settings.

Ventilator Management of Patients with ARDS

FLUID MANAGEMENT

- Once patients are out of shock adopt a conservative fluid management strategy.
- Use diuretics or fluids to target a central venous pressure (CVP) of <4 or a pulmonary artery occlusion pressure (PAOP) of <8.

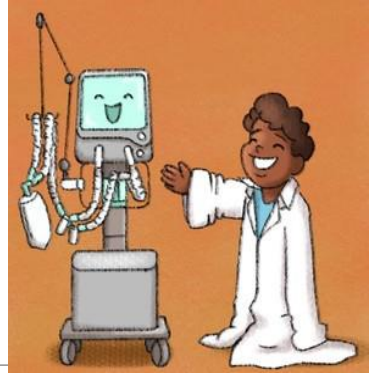
LIBERATION FROM MECHANICAL VENTILATION

- Daily interruption of sedation
- Daily screen for spontaneous breathing trial (SBT)
- SBT when all of the following criteria are present:

(a) FiO2 < 0.40 and PEEP < 8 cm H2O
(b) Not receiving neuromuscular blocking agents
(c) Patient is awake and following commands.
(d) Systolic arterial pressure > 90 mm Hg without vasopressor support
(e) Tracheal secretions are minimal, and the patient has a good cough and gag reflex.

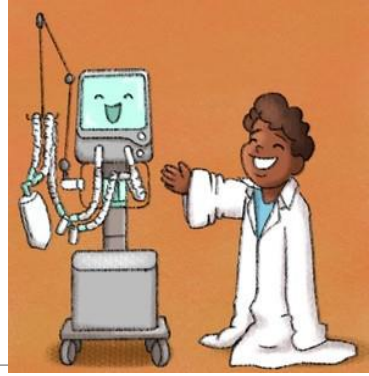
SPONTANEOUS BREATHING TRIAL

- Place patient on 5 mm Hg pressure support with 5 mm Hg PEEP or T-piece.
- Monitor HR, RR, oxygen saturation for 30-90 minutes.
- Extubate if there are no signs of distress (tachycardia, tachypnea, agitation, hypoxia, diaphoresis).



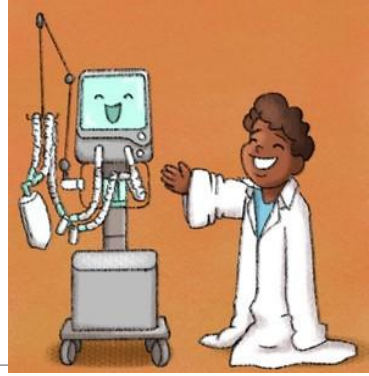
Clinical and physiological considerations in the management of patients with COVID-19-associated ARDS

Timing of intubation



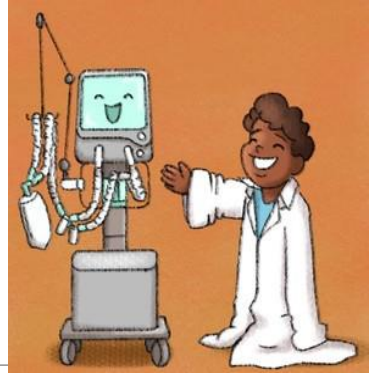
- No high-quality clinical trial evidence addressing optimal timing of intubation in ARDS is available
- Intubation might be beneficial in patients with high respiratory drive and at high risk of patient self-inflicted lung injury
- NIV has been associated with worse outcomes when PaO 2/FiO2 ratio <150
- Detrimental consequences of intubation and invasive ventilation (eg, related to sedation,paralysis, and endotracheal tube complications) might outweigh benefits, especially in patients with mild hypoxemia and without high respiratory drive or work of breathing

Tidal volume



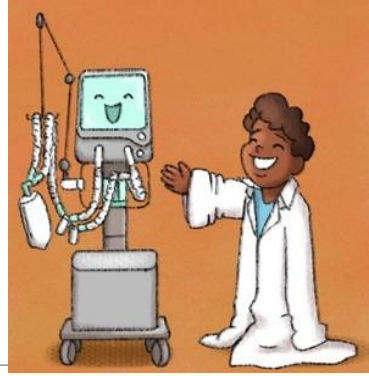
- Low VT ventilation results in improved outcomes in patients with and without ARDS and should be the starting point for ventilatory management of patients with ARDS (ie, 6 mL/kg PBW)
- Lower VT as needed to 4 mL/kg PBW to keep plateau pressure <30 cm
- Liberalise VT (up to 8 mL/kg PBW) in patients who are double triggering, or if inspiratory airway pressure decreases below PEEP, keeping plateau pressure <30 cm Ideally, keep driving pressure ≤14

PEEP



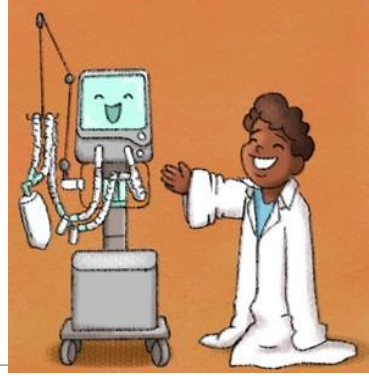
- Individualise PEEP
- consider higher PEEP in patients with evidence of higher potential for recruitment (eg, as suggested by CT scan or recruitment to inflation index) or with a body habitus or clinical exam that suggests high pleural pressures are likely
- Higher PEEP can be harmful in patients with low recruitability, who have hypoxemia due largely to pulmonary vascular pathology; high PEEP can lead to adverse hemodynamic effects or barotrauma

Prone positioning



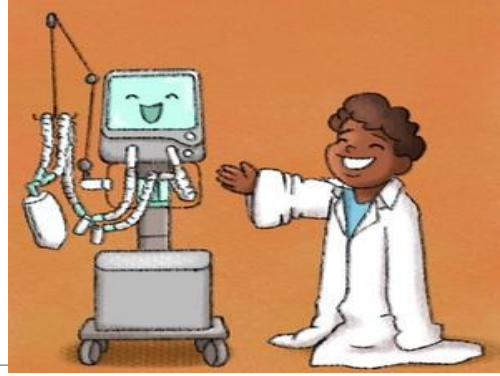
- Prone positioning is associated with improved outcomes in patients with moderate or severe ARDS, with improved ventilation or perfusion matching, more homogeneous distribution of ventilation, and reduced risk of ventilator-induced lung injury
- In the absence of contraindications, use prone positioning in mechanically ventilated patients with PaO2/FiO2 ratio <150

Acute cardiogenic pulmonary edema and CHF

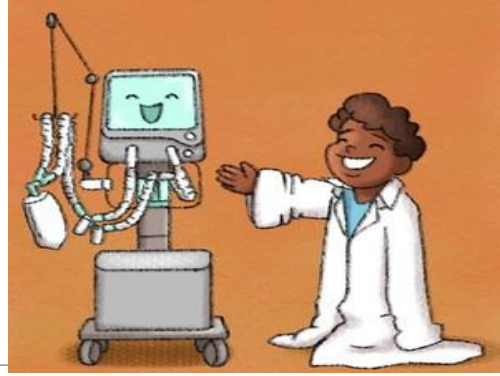


- Many patients can be successfully managed with drug therapy and do not require MV support
- However, MV may be indicated when severe heart failure leads to increased myocardial work, increased WOB, and hypoxemia.
- In patients with left ventricular failure the use of positive pressure, particularly PEEP can effectively reduce the size of the heart and therefore reduce venous return and reduce preload to left ventricles

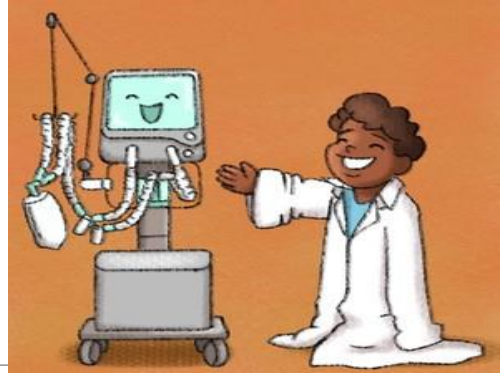
Guidelines for patients with CHF



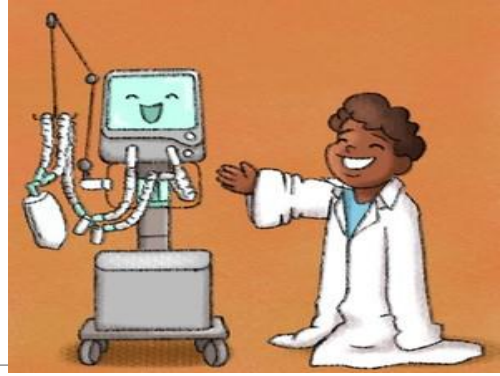
- Select a mode of ventilation that reduces WOB
- This may be as simple as noninvasive mask CPAP
- NIV by mask CPAP may improve oxygenation, reduce PaCO2, reduce the WOB, and reduce myocardial work
- NIV in patients with CHF may allow sufficient time for pharmacologic treatment to become effective.



- When life-threatening hypoxemia occurs with severe CHF, PEEP or PPV may have beneficial effects on myocardial function and improve oxygenation
- Careful evaluation of the effects of PPV on hemodynamics is essential
- This may include the use of a pulmonary artery catheter in severe cases, particularly if $PEEP_E$ greater than 10 to 15 cm H2O is used.



- The use of VC- or PC-CMV is recommended to minimize spontaneous breathing, which may divert increased blood flow and oxygen consumption to the respiratory muscles
- V_T range is moderate from 6 to 8 mL/kg
- Set f from 10 or more breaths/min
- Peak flows 60 L/min or greater using either descending or constant waveforms
- TI range is 1 to 1.5 seconds



- Set a PEEP of 5 to 10 cm H2O to support the cardiac function
- Start FIO2 at 1.0 and titrate quickly with SpO2 to maintain SpO2 greater than 90% to 92%
- Monitor SpO2, ABGs, urine output, electrolytes, and systemic hemodynamic status.

TABLE 7-1 Initial Ventilator Settings Based on Pulmonary Disorder*

Lung Disease	Mode	V_T (mL/kg IBW)	Rate (breaths/min)	Flow (L/min)	Flow Waveform	T_I (sec)	PEEP (cm H_2O)	F_IO_2
Normal lungs	VC- or PC-CMV	6-8	10-15	60	Descending or constant	1	≤5	≤0.5
COPD†	VC- or PC-CMV	6-8	8-12	>60 (80-100)	Descending or constant	0.6-1.2	≥5 or 50% of intrinsic PEEP	<0.5
Neuromuscular disorder	VC-CMV	6-8	8-12	≥60	Descending or constant	1	5	0.21
Asthma	VC- or PC-CMV	6-8	10-14	60-70	Descending	≤1	Only to offset intrinsic PEEP and improve triggering	≥0.5
Closed head injury	PC- or VC-CMV	6-8	15-20	60	Descending or constant	1	0-5 with caution Only in severe hypoxemia	1.0
ARDS	PC- or VC-CMV	4-8	12-35	≥60	Descending or constant	1	5 to >15	1.0
CHF	VC- or PC-CMV	6-8	≥10	≥60	Descending or constant	1-1.5	5-10	1.0